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Adult Females and Pubic Bone Growth

KATHLEEN FULLER*
Department of Anthropology, University of Kansas, Lawrence, Kansas 66045

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ABSTRACT Previous research (Tague [1994] Am. J. Phys. Anthropol. *95:*27–40) has shown an age effect in pubic bone length among adult women. Tague found that in three prehistoric Native American skeletal samples, women aged 18–24 had a significantly shorter linea terminalis than did women aged 25 and older. The purpose of this research is to determine whether such a difference can be discerned in other female skeletal samples.

Three female skeletal samples were used in this analysis: 75 African-American and 42 European-American females aged 18–39 from the Hamann-Todd Collection (collected between 1893 and 1938; Iscan, 1990) and 99 African-American females aged 18–39 from the Terry Collection (collected between 1914 and 1965; Cobb, 1933; Iscan, 1990). Several chord measurements of pubic bone length along the linea terminalis were analyzed by one-tailed *t*-tests of the separate samples subdivided into two age groups: 18–24 and 25–39 years. Of 15 comparisons between age groups, none differed significantly by age group within each sample. It is concluded that the observed significant difference in pubic bone length in the Native American female skeletal samples cannot be replicated in other samples and that there is no age effect on pubic bone length in the samples tested in this analysis. Tague's findings reflect either the occurrence of late menarche in prehistoric populations or differential survivorship. Am J Phys Anthropol 106:323–328, 1998.

In an intriguing study of female Native American skeletal material from three populations, Tague (1994) found a correlation between the presumed age of the specimen and the length of the pubic bone. Older females (aged 25 and over) had a significantly longer linea terminalis on average than did females aged between 18 and 24. Since Tague's populations, Indian Knoll, Pecos Pueblo, and Libben, are prehistoric, he determined the sex of each specimen using greater sciatic notch shape and the Phenice technique (1969) and estimated the age of each specimen using the pubic symphysis, auricular surface of the ilium, and epiphyseal fusion.

Tague (1994) did not find differences in pubic length between older and younger males and concluded that the males had basically completed pubic growth by age 18. He further concluded that sexual dimorphism in pelvic shape was due in part to the continued growth, into the third decade, of the female pubic bone. However, Tague also noted for the females in his study, "that pelvic inlet circumference was relatively confined among young adult females. The implication is that birth among these females was probably difficult" (Tague, 1994:38). Therefore, the difference in pubic bone length

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*Correspondence to: Kathleen Fuller, Anthropology Dept., 622 Fraser Hall, University of Kansas, Lawrence, KS 66045. E-mail: kfuller@kuhub.cc.ukans.edu

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between the younger and older cohorts of women could be due to differential maternal mortality.

Tague concluded that his study could not determine which explanation was most probable, though he seemed to lean toward continued growth of the pubis in adult females as opposed to differential maternal mortality. The research described in this article is an attempt to both replicate Tague's findings (using three different female skeletal samples) and to determine which of Tague's two explanations is most probable. The samples used in this analysis are taken from the Hamann-Todd (African American and European American) and Terry (African American) collections. Since the skeletal material in these collections is of known sex and age, this will alleviate any possible biases introduced into Tague's analysis due to having to estimate sex and age in the Native American samples.

METHODS

Human female skeletal material from the Hamann-Todd Collection at the Cleveland Museum of Natural History and from the Terry Collection at the Smithsonian was used in this analysis. The skeletons of 75 African-American and 42 European-American females between the ages of 18 and 39 (Hamann-Todd Collection) and 99 African-American females between the ages of 18 and 39 (Terry Collection) were measured. This data set consists of skeletons of females of known age in the primary child-bearing age category of 18–39 (Cobb, 1933; Iscan, 1990).

Three chord measurements of pubic length are utilized in this study (see Fig. 1): arcuate chord (the distance from the most anterior point on the auricular surface of the ilium to the most superior point on the symphysis), acetabulosymphyseal chord (the distance from the superior point on the symphysis to the most medial point on the acetabular rim), and iliopectineal eminence–pubic symphysis chord (the distance from the most superior point on the arcuate line where the ilium joins the pubic bone to the most superior point on the symphysis). Also utilized for comparative purposes is the iliopectineal eminence–auricular surface chord (the distance from the most anterior point on the auricular surface of the ilium to the most superior point on the arcuate line where the ilium joins the pubic bone). In addition, while I use chords and Tague used an arc, the double chord measurement of iliopectineal eminence–pubic symphysis chord plus iliopectineal eminence–auricular surface chord is approximately equivalent to the linea terminalis arc used by Tague. I also examine three other measures of pubic bone length. If there is an age difference in pubic bone length, this should be apparent in these several measures of the pubic bone.

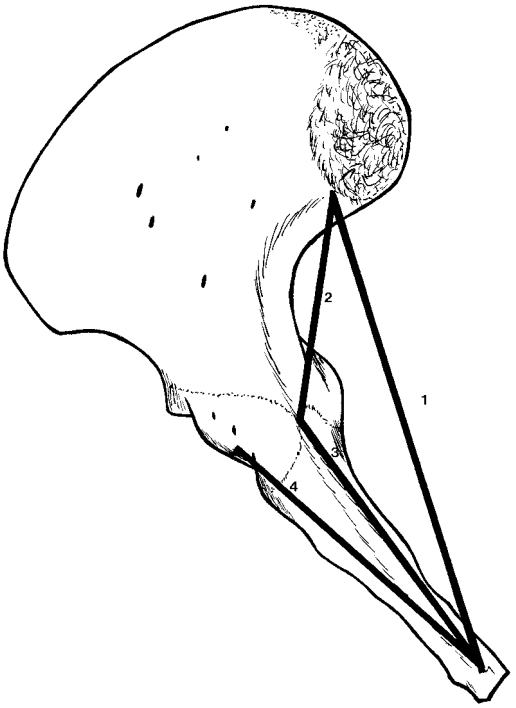

Fig. 1. Four chord measurements of pubic length: 1, arcuate chord; 2, iliopectineal eminence–auricular surface chord; 3, iliopectineal eminence–pubic symphysis chord; 4, acetabulosymphyseal chord.

One-tailed *t*-tests ($\alpha = .05$) of each of the five chord measurements of pubic length were analyzed for each of the three separate samples subdivided into two age groups: 18–24 and 25–39 years. In all, 15 *t*-tests were done.

RESULTS

The results of the *t*-tests are shown in Table 1. Of the 15 *t*-tests, none differed

TABLE 1. T-*tests comparing pubic bone length (in cm) in females 18–24 and 25–39 years*

	African American (H-T)		European-American (H-T)		African American (T)	
	18–24 yr (N = 24)	25–39 yr (N = 51)	18–24 yr (N = 4)	25–39 yr (N = 38)	18–24 yr (N = 23)	25–39 yr (N = 76)
Arcurate chord						
$\bar{X}$	10.80	11.07	11.39	11.32	11.11	11.06
SE	0.152	0.120	0.160	0.140	0.181	0.087
t	−1.39 ns		0.298 ns		0.259 ns	
Acetabulo-sympheseal chord						
$\bar{X}$	5.63	5.84	6.37	6.01	5.77	5.70
SE	0.176	0.083	0.488	0.093	0.095	0.072
t	−1.09 ns		0.733 ns		0.623 ns	
Iliopectineal eminence–pubic symphysis chord						
$\bar{X}$	6.42	6.54	6.45	6.64	6.89	7.06
SE	0.122	0.076	0.355	0.081	0.126	0.058
t	−0.823 ns		−0.537 ns		−1.226 ns	
Iliopectineal eminence–auricular surface chord						
$\bar{X}$	6.81	6.90	7.07	7.06	6.14	6.13
SE	0.168	0.102	0.219	0.097	0.147	0.074
t	−0.463 ns		0.054 ns		0.047 ns	
Iliopectineal eminence–pubic symphysis plus iliopectineal eminence–auricular surface double chord						
$\bar{X}$	13.23	13.44	13.52	13.70	13.04	13.20
SE	0.171	0.120	0.187	0.136	0.174	0.098
t	−1.00 ns		−0.79 ns		−0.814 ns	

H-T = Hamann-Todd Collection; T = Terry Collection.
*$P < 0.05$; Bonferroni Protection Level: $P = 0.001$.

significantly by age group within each sample. As can also be seen in Table 1, the mean lengths of the various chords do not differ significantly by age in the three skeletal samples. In fact, some of the means are remarkably similar.

Since the 18–24 age subsets for the European-American (H-T) and the African-American (T) samples were quite a bit smaller than the 25–39 age subsets, *t*-tests were also run on two differing age subsets (18–30 and 31–39) which more evenly split the samples (n's = 20 and 22 for H-T and 53 and 46 for T). The results (not shown) were the same except for a significant difference for the iliopectineal eminence–pubic symphysis plus iliopectineal eminence–auricular surface double chord ($P = .03$) for the Terry African-American sample. When many variables of two populations are analyzed by *t*-tests, it is necessary to use the Bonferroni Protection method to make the alpha more stringent in order to avoid the chance occurrence of significant differences at the 0.05 level when, in fact, the two populations do not differ significantly. For instance, in an analysis of 20 variables, one test could be significant at the 0.05 level by chance. The more stringent Bonferroni Protection level is determined by dividing 0.05 by the number of variables to be analyzed. If variables remain significantly different at the Bonferroni Protection level, then one has more confidence that the two populations under analysis are, indeed, significantly different (Moses, 1986). The Bonferroni Protection level for the analysis discussed in this article is 0.01; therefore, none of the *t*-tests are significantly different. Also, the age groupings do not match those used by Tague.

DISCUSSION

The results of this research have failed to replicate Tague's (1994) findings. While Tague used the length of the linea terminalis and this study did not, the double chord of iliopectineal eminence–pubic symphysis plus iliopectineal eminence–auricular surface is approximately equivalent to the linea terminalis arc. In addition, several other mea-

sures of pubic bone length failed to find significant differences by age subset.

Failure to replicate Tague's results cannot be due to a secular trend in body size in the younger age cohort in my samples. Those in the younger age cohort were both born and died during the same time periods as did those in the older age cohort. In the Hamann-Todd African-American sample, the younger age cohort was born between 1894 and 1913, while those in the older age cohort were born between 1877 and 1910; however, 69% of the older cohort were born between 1894 and 1910. For the Hamann-Todd European-American sample, the younger age cohort was born between 1893 and 1924, while the older age cohort was born between 1878 and 1904, with 42% of the older cohort born between 1893 and 1904. In the Terry African-American sample, the younger age cohort was born between 1901 and 1930, while the older age cohort was born between 1887 and 1934, with 59% of the older cohort born between 1901 and 1934. Lack of a secular trend between the two age cohorts is confirmed by *t*-tests (not shown) on acetabular breadth, an estimator of body size. There were no significant differences between age cohorts within a sample. Therefore, the failure to replicate Tague's results is not due to a secular trend in body size in the younger age cohort masking the continued growth of the pubic bone.

A review of the literature on growth and development does not support significant further growth of the female pubic bone past adolescence. Greulich and Thoms (1944) did a longitudinal pelvic X-ray study of girls who were between ages 5 and 15 when the study commenced. The girls were examined yearly for at least 4 years. Greulich and Thoms found that the speed with which pelvic changes occurred was correlated with the maturation of the girl: rapidly if maturation was early, more slowly if maturation was delayed. Of the 10 girls who were examined after puberty (at approximately age 18), Greulich and Thoms concluded that very little pelvic inlet growth occurred once the puberal period of pelvic remodeling (approximately 18 months) was complete. Pelvic remodeling was associated with the general pubertal growth spurt; menarche began soon after the growth spurt.

Moerman (1981) also analyzed pelvic X-rays taken during the Fels longitudinal study. The X-rays used in this study were of children between 8 and 18 years of age. Moerman found that sexual dimorphism in body size was reduced in those aged 8 years, while pelvic differences increased. She considered that this was due to earlier maturation in females which resulted in their having larger body size for age. When males and females were compared on the basis of bone maturation (adductor sesamoid ossification) the relative sexual dimorphism of the pelvis decreased, while body size sexual dimorphism increased. In early adolescence, holding body size and maturation constant, the pelvis is not sexually dimorphic. It is during the adolescent period that differential growth of the pelvis occurs in males and females, leading to the sexually dimorphic adult pelvis. In males, growth in those dimensions related to pelvic capacity (at the inlet, midplane, and outlet) decelerates as growth in stature decelerates. However, growth in those same dimensions in females decelerates more slowly than does growth in stature so that pelvic capacity in females, corrected for height, is larger than pelvic capacity in males. Moerman also found that although 95% of adult height was attained by menarche, the pelvis in girls was still relatively small at that point, with 13% of growth remaining for the inlet diameter.

A later study by Moerman (1982) found that age at menarche was an important factor in determining pelvic capacity. Hoff et al. (1985) defined this variable as gynecological age (GA): chronological age minus age at menarche. Moerman found that by gynecological age 3 (her MA [years from menarche] 2), 99% of adult stature and about 96% of the pelvic inlet transverse diameter length had been achieved. While growth in stature was virtually complete, growth continued in inlet size. Based on Table 2 of Moerman (1982), the largest percentage of remaining pelvic growth occurs during the first year postmenarche (GA 1). For the pelvic inlet transverse diameter, this means that during GA 1, the transverse diameter achieves 87% of

its adult length. In GA 2, it is 93% of adult length; 96.1% in GA 3; and 98.3% in GA 4. Growth rapidly decelerates with increasing GA. If menarche occurred at about age 13, growth of the pelvic inlet transverse diameter was virtually complete by age 18.

Coleman (1969) found that the primary factor in producing sexual dimorphism in the pelvic inlet was the continued growth in females of the pubic bone, specifically along the medial border. Since the bones on both sides of the inlet are growing, the end result is a pelvic inlet which has a larger transverse diameter in females than in males. Therefore, sexual dimorphism in the pelvic inlet transverse diameter is due to a longer period of growth along the superior/medial margin of the pubic bone in females, and such growth is over 98% complete by GA 4.

Since Tague's Native American samples are prehistoric, it is possible that menarche occurred much later in adolescence than is the case with the studies cited above or with the skeletal samples used in my analysis. If menarche did not occur, on average, until age 16 or later, as is true among some modern forager populations (Malcom, 1969; Van Arsdale, 1978a,b) then pubic bone growth could have continued until age 20 or 21, on average. This would also explain Tague's findings and my failure to replicate these findings. Pubic bone growth is correlated with gynecologic age. If menarche occurs late in adolescence in a particular population, then pubic bone growth will be completed at a commensurately later age in that population.

In modern populations living in the United States, where menarche occurs early in adolescence, pubic bone growth is complete by about age 18. This is supported by statistics on the outcomes of teen pregnancies. Researchers have found that the risks associated with the pregnancies of teens 16–17 years old and older do not differ significantly from those of women between 20 and 32 years old (Fisk and Shweni, 1989; Friede et al., 1987; Hoff et al., 1985; Maso et al., 1988; Naeye, 1981; Satin et al., 1994). Since average age at menarche in the United States is between 12.1 and 12.5 years (Hoff et al., 1985), teens 16–17 years old have generally completed pelvic inlet growth based on gynecological age. Younger teens, especially those in GA 1 and GA 2, are more likely to suffer from cephalo-pelvic disproportion (Moerman, 1982).

Since growth of the pubic bone continues into GA 4, it is probable that some of the females in the younger age cohort of Tague's sample were still in stage GA 1 or GA 2 and had not yet completed pelvic growth. However, whether the smaller pelves of the younger cohort are attributable to an early GA stage as opposed to those in the older group who had completed pelvic growth, or are smaller due to other factors, the end result is the same. The most parsimonious explanation, also put forward by Tague, is that the Native American material is the result of differential survivorship. Women with small pelves, particularly at the inlet, have a higher probability of fetal cephalopelvic disproportion and thus a higher mortality rate than do women with greater obstetric capacity (Greulich and Thoms, 1938; Neer, 1975; Riggs, 1904; Thoms, 1935, 1946); and women who are of young gynecologic age also have increased rates of cephalopelvic disproportion (Moerman, 1982).

Modern Native American women have among the heaviest infants in the world (Meredith, 1970), averaging between 3,400 g and 3,800 g (Adams and Niswander, 1968). Since fetal head size is correlated with body weight (Harris, 1984; Smeltzer, 1986), if prehistoric Native American women also gave birth to large infants, cephalopelvic disproportion, and, possibly, shoulder dystocia, would occur in the women with smaller pelves. Maternal mortality was probable since operative interventions, which became relatively common in the late 19th century (Riggs, 1904), were improbable.

The only way to test which factor (late menarche or maternal mortality) was most probable would be to examine a skeletal population with known age at menarche and known cause of death. While the Hamann-Todd and Terry collections include information on cause of death for most specimens, the age at menarche is unknown. The single largest cause of death in the combined Hamann-Todd and Terry samples is tuberculosis (34% of total), with pneumonia a distant second. Since these causes of death are

not clearly related to maternal mortality and since age at menarche is unknown, it is impossible to decide which factor, delayed menarche or maternal mortality, is the most probable explanation for Tague's findings.

Based on the analysis described in this article, Tague's results cannot be replicated among these samples. Therefore, continued pubic bone growth is not universal to all humans. His findings reflect either the occurrence of late menarche in prehistoric populations or differential survivorship.

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